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EVALUATION OF THE BELL 205A-1 TURBOJET HELICOPTER AND SPRAY SYSTEM FOR FOREST APPLICATION OF INSECTICIDE

by

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ABSTRACT

The atomization and distribution of insecticide sprays produced from a Bell 205A-1 turbojet helicopter and spray system were evaluated under open ground conditions. The degree of atomization was within the same range as that produced by the smaller helicopters, and the acceptable swath width was wider. In some flights there were two very high deposit peaks with low deposit between those peaks, similar to that produced by a fixed-wing aircraft spraying at a low height above the ground. By visual observation, the main rotor vortexes appeared stronger and more pronounced than those of smaller helicopters. On a large forest spray program the Bell 205A-1 sprayed an average of 877 acres per hour at an application rate of 1 gallon per acre for a cost of $1.78 per acre.

KEYWORDS: Helicopters, pesticide application methods.

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REST SERVICE - U.S. DEPARTMENT OF AGRICULTURE - PORTLAND, OREGON

INTRODUCTION

In recent years, the use of helicopters for forest pesticide application has increased. Most use, however, has been on small acreages and with small helicopters such as the Bell 47 series and Hiller 12E series. These small aircraft spray at speeds between 45 and 60 miles per hour and carry loads between 30 and 120 gallons depending on the density of the pesticide and altitude of operation. They can operate from small clearings close to the area being treated and are an excellent tool for treating small and irregular areas because of their maneuverability and slow speed. Where large acreage is to be sprayed, these helicopters are generally considered to be economically unsuitable because of their small payload.

An aerial spray test, to control the Douglas-fir tussock moth with the insecticide Zectran, over several thousand acres was planned for June 1973. The size of the test area was too large for the smaller conventional helicopters; therefore a larger helicopter, the Bell 205A-1 turbojet, was considered.

In the Northwest States, the Forest Service is currently using the Bell 205A-1 turbojet for transporting cargo and personnel, rappelling fire crews, and dropping water on fires. There were no spray data available for the 205A-1; however the helicopter was available locally, and the Forest Service initiated an evaluation of it for possible use on the Zectran spray test.

This was a cooperative study between the Pacific Northwest Forest and Range Experiment Station and Region 6, Insect and Disease Control Branch, of the U.S. Forest Service.

DESCRIPTION OF SPRAY SYSTEM

The helicopter and spray system (fig. 1A) were furnished and operated by Evergreen Helicopters, Inc., of McMinnville, Oregon.[2/] The helicopter was a Bell 205A-1, with a 1,400-horsepower gas turbine engine which has a 4,000-pound lifting capacity and cruises at 110 knots. The spray system (fig. 1B and 1C) was designed for Evergreen Helicopters, Inc., by Agrinautics of Las Vegas, Nevada. The internally mounted system consisted essentially of a 400-gallon fiberglass spray tank, a 25-horsepower gasoline engine with a direct drive pump, and left and right spray booms. The spray tank was mounted on an aluminum frame which was secured to the floor utility studs.

[2/] The use of trade, firm or corporation names is for the information and convenience of the reader. Such use does not constitute endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

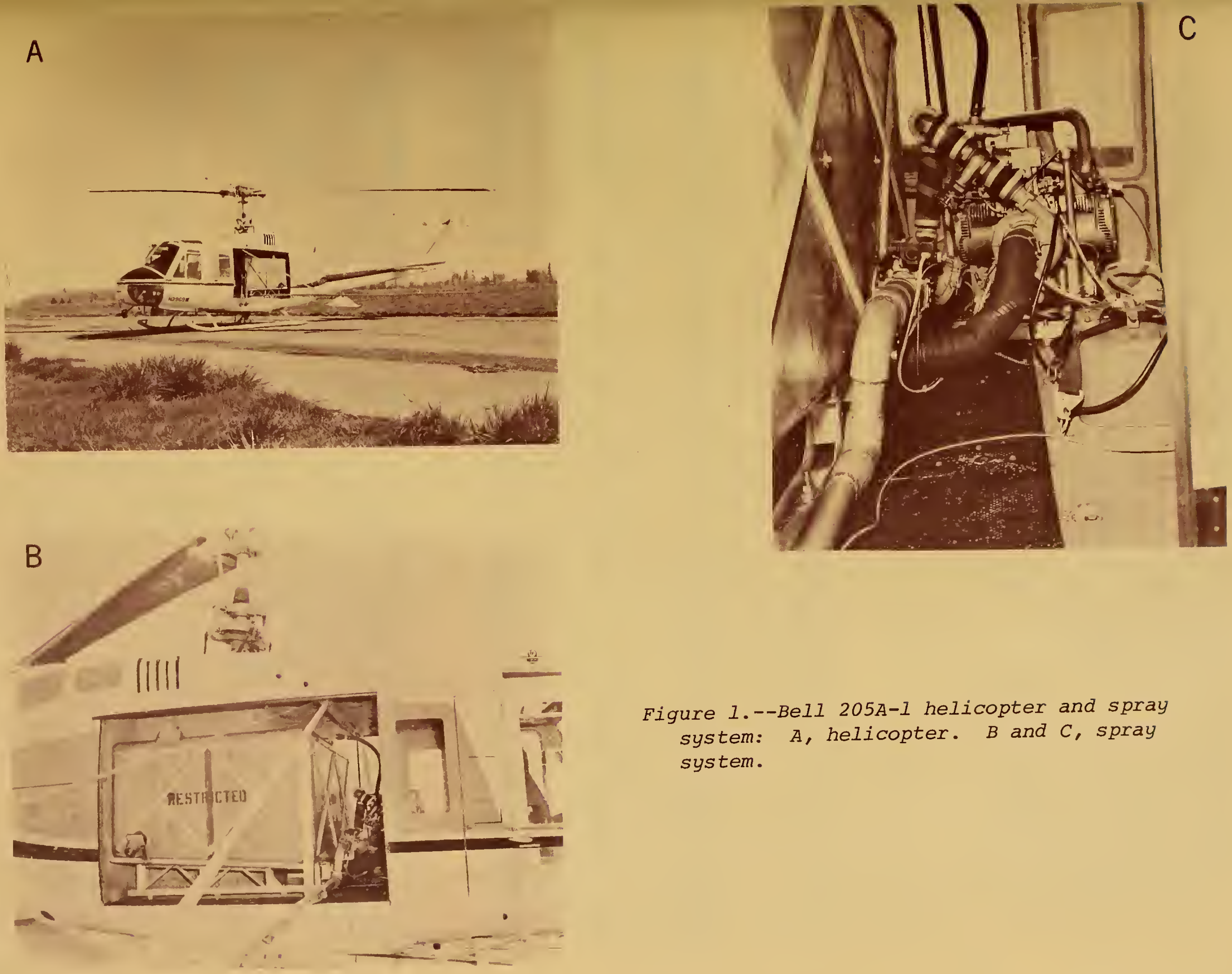

Figure 1.--Bell 205A-1 helicopter and spray system: A, helicopter. B and C, spray system.

The tank could be filled from either side of the helicopter. The pump was driven by a 25-horsepower Onan gasoline engine. The pump and engine were secured to the floor utility studs as a unit. The pump was capable of pumping 300 gallons per minute at 100 pounds per square inch and maintain recirculation within the spray tank. A master control box was installed in place of the pilot's map case. The master control box included a throttle, RPM gage, pump pressure gage, circuit breaker switch, start switch, and master ignition switch. There was also a boom pressure gage mounted on the right-hand side of the instrument panel. The boom on-off valve was controlled by a switch mounted on the pilot's cyclic stick. Fluid lines between the pump and tank were of a high pressure rubber type. A 12-volt battery was used for starting the pump engine and recharged by the aircraft engine generator. Both spray booms (left and right) were 24 feet long and reduced from a diameter of 2 inches to 1-1/2 inches at a point 12 feet, 6 inches outboard. The boom was made of aluminum alloy, and each side supported by three aluminum tubes and three stainless steel cables leading from the airframe hard points to a triangular brace plate which was attached to the midsection of each boom. These brace plates caused drooling whenever nozzles were placed near them. To prevent drooling, nozzles were not placed within 18 inches on either side of these plates. There were ports on each boom (left and right) for 51 nozzles spaced 5 inches apart. Because the spray system was internally mounted and the crossover line to the left and right booms was located inside the ship, there was no port for nozzles over a 12-foot, 8-inch midsection. All nozzles were Spraying Systems diaphragm teejet with flat spray tips. The booms could be rotated to adjust the nozzle orientation with respect to the direction of flight. There was no emergency dump on this system.

TEST PROCEDURE

The purpose of these tests was to obtain data concerning the swath width and pattern produced by the 205A-1 helicopter and spray system when spraying at different airspeeds and spray heights, and to determine the degree of atomization of sprays recovered from this system using different sizes of nozzle tips. The variables tested were: (1) Spraying Systems flat spray tips No. 8002, 8010, and 8020, (2) spraying heights of 50, 100, and 200 feet, and (3) spraying speeds of 50, 70, and 90 miles per hour.

The spray formulation was the same as that used for the insecticide Zectran, except that there was no active ingredient. This formulation consisted of nine parts of #2 fuel oil mixed with one part Dowanol TPM (tripropylene glycol methyl ether). To each gallon of spray, 3.785 grams (0.1 percent weight to volume) of the fluorescent tracer Rhodamine B Extra base (GAF Corp.) was added to facilitate deposit assessment.

Initially the spray system was calibrated at a spray pressure of 60 pounds per square inch for an application rate of 1 gallon per acre using an assumed swath width of 200 feet. To determine if the spray was being delivered at equal rates throughout the boom, flow rates were established for each nozzle size at two inboard and two outboard positions on the boom. The formulation was sprayed through the nozzles and collected for 1 minute, then measured in a graduate cylinder thus providing the flow rate per minute. All nozzles were oriented forward and down at 45 degrees with respect to the line of flight. The nozzle arrangement on the boom for each treatment parameter is shown in figure 2.

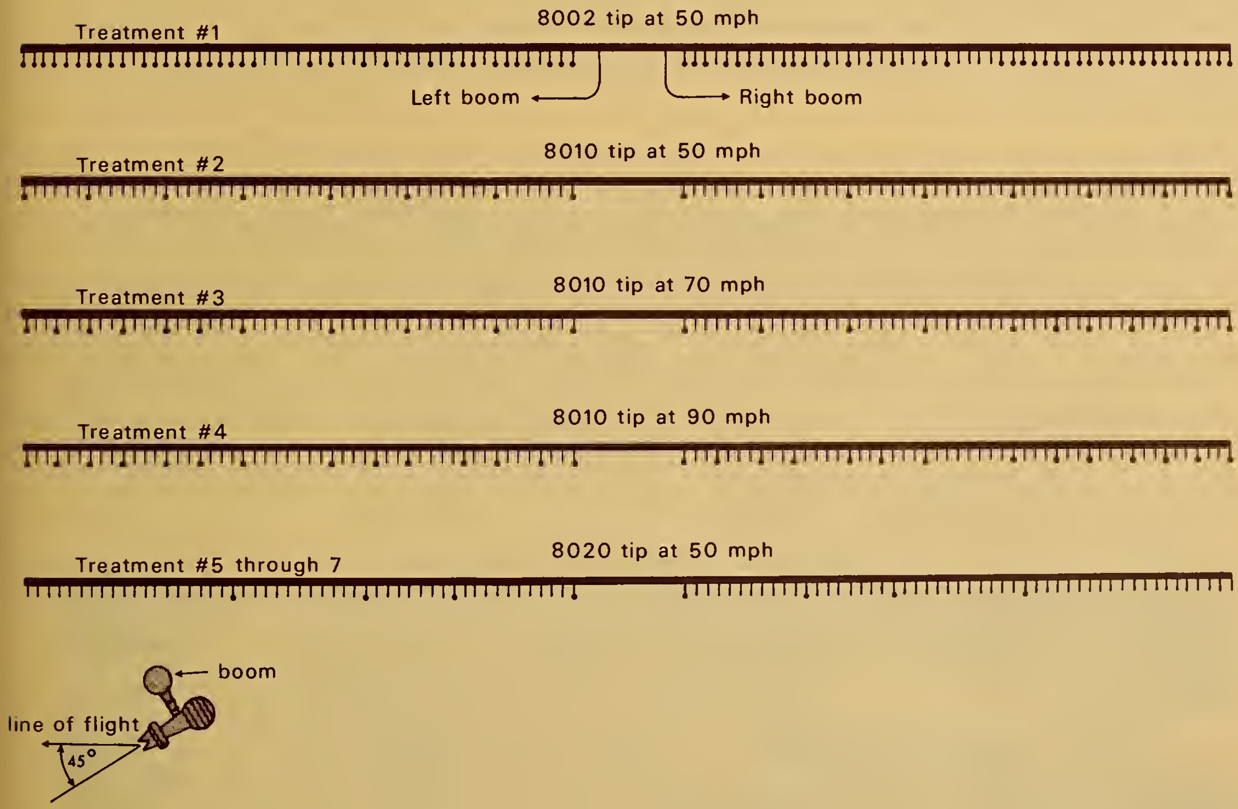

Figure 2.--Schematic diagram showing the nozzle arrangement on the boom for each treatment parameter.

The procedure used for determining the spray distribution was similar to that reported by Isler and Yuill (1964) for fixed-wing aircraft and by Isler and Maksymiuk (1961) for helicopters. A 500-foot rotating platform shown in figure 3 was used for holding the deposit sampling surfaces. One 6- by 6-inch aluminum plate and one white 4- by 5-inch Kromekote card were positioned at 10-foot intervals along the entire length of the platform. The platform was rotated for each test flight until it was perpendicular to the prevailing wind. The aircraft was flown upwind over the platform at a predetermined spot and at a designated speed and altitude. The spray was turned on 500 feet downwind of the platform and off 1,500 feet upwind of the platform. After turning off the spray, the pilot continued in a straight line for 5 seconds, then made a large turn and landed downwind of the platform so that the air currents in the direct vicinity of the sampling stations would not be disturbed.

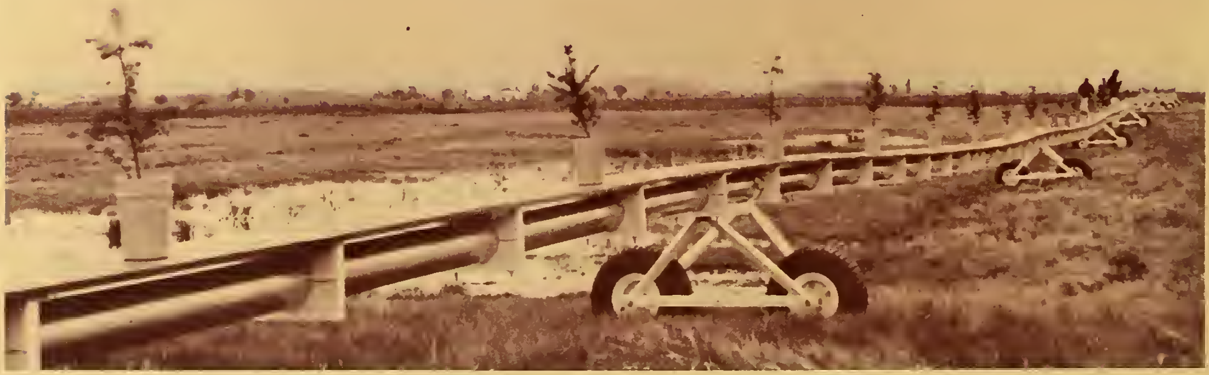

Figure 3.--A 500-foot rotating platform for sampling aerial spray deposit.

The meteorological conditions were monitored for each test flight, as shown in table 1. Most flights were made in the early morning, when spraying conditions are usually favorable. There was a total of 32 test flights, of which 9 were discarded because the wind changed direction during flight and blew off a large part of the spray from the edge of the platform.

The spray was allowed to settle for 15 to 20 minutes; then the deposit sampling surfaces were collected and placed in slotted boxes to prevent smudging of drops and contamination of one surface by another. The boxes were then transported to the laboratory for analysis.

The spray drops on the white Kromekote cards were counted and sized using an ultraviolet illuminator and dissecting microscope. The spray atomization was determined by the drop-size spectra method (Maksymiuk 1964). The number of drops are expressed in number per square centimeter of surface area, and the size (atomization) is expressed as the volume median diameter (vmd).[3]

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[3] Volume median diameter (vmd) is the drop diameter satisfying the requirement that half of the volume of liquid is in drops smaller and half is in drops larger than the vmd.

Table 1.--*Summary of meteorological data*

Flight number	Date (1973)	Time (a.m.)	Wind conditions		Temperature (°F)			Relative humidity	Sky condition
			Miles per hour	Gusty	At 2 feet	At 4 feet	At spray height		
								Percent	
3	3-30	5:54	3	no	44.5	45	42.8	88	overcast
4	3-30	6:28	2-3	yes	45	45	42.8	88	overcast
5	3-30	8:15	2-3	yes	45.5	46	44.6	87	overcast
6	3-30	8:40	2-3	mildly	45.5	46	44.6	88	overcast
8	4-2	6:10	1	no	27.5	28	30	88	clear
9	4-2	6:37	2-3	no	29.5	30	30	87	clear
10	4-2	6:55	1	no	35	34	32	80	clear
12	4-2	8:15	3-4	mildly	40	39	39.2	80	clear
13	4-2	9:15	5-6	yes	46.5	48	39.2	77	clear
14	4-2	10:38	--	slightly	52	52	41	59	clear
15	4-3	6:41	1	no	37	36	30	78	clear
16	4-3	7:24	1-2	no	43	42	35.6	76	clear
17	4-3	8:00	0-1	no	53	51	39.2	57	clear
20	4-4	5:43	2	no	34.5	35	37.4	90	clear
23	4-4	7:31	0.5	no	44	43	42.8	80	clear
24	4-4	8:00	0.5	no	48	45	44.6	78	clear
25	4-4	8:36	1-2	no	50	48	46.4	77	clear
26	4-4	9:08	2-4	yes	51	50	50	75	clear
27	4-4	9:45	0.5	mildly	54	53	53.6	60	clear
29	4-4	10:55	3-4	yes	62	61	57.2	52	clear
30	4-6	5:50	2	no	33	34	--	95	clear
31	4-6	6:18	2	no	34	35	--	95	clear
32	4-6	7:30	4-5	yes	46	45	--	86	clear

The spray deposit was washed from each of the aluminum plates with 10 milliliters of 95-percent ethanol. The deposit recovered from the plates was quantitated fluorometrically, using a Model 430 Turner Spectrofluorometer, similar to the method described by Yates and Akesson (1963). The quantity of spray is expressed in gallons per acre (gpa).

RESULTS AND DISCUSSION

Calibration

Flow rates for each of the nozzle tip sizes at the different locations along the boom are shown in table 2. Even though there was some variation at different locations along the boom, there was no particular location that was consistently high or low. The spray material seemed to be displaced throughout the boom at nearly equal rates. The gasoline-driven spray pump, which is independent of the helicopter engine, allowed for easy calibrations on the ground.

Swath Width

Table 3 is a summary of the mean swath width, swath deposit, percent recovery, and atomization for each treatment. A comparison of nozzle tip sizes (treatments 1, 2, and 5) shows that the larger tips produced wider acceptable swaths. For our purpose an acceptable swath width was defined as that portion of the swath having a deposit level of 0.1 gpa or greater at each sampling point throughout the swath. The smallest nozzle tips (treatment 1) produced the finest atomization which drifted farther and resulted in

Table 2.--*Summary of flow rate data for nozzles positioned at various points along the boom*

Location of nozzle	Spray pressure	Mean flow rate (gallon per minute)[1/]		
		Nozzle tip 8002	Nozzle tip 8010	Nozzle tip 8020
	Pounds per square inch			
Left inboard	60	0.26	1.37	2.58
Left outboard	60	.26	1.34	2.61
Right inboard	60	.29	1.33	2.38
Right outboard	60	.30	1.41	2.57
Mean		.28	1.36	2.53

[1/] There were three replications per nozzle size per location.

Table 3.--*Summary of the mean swath width, swath deposit, percent recovery, and atomization for each treatment*

Treatment	Number of flights	Nozzle		Spraying		Swath width1/	Swath deposit		Percent recovery	Atomization, vmd
		Tip size	Number	Height	Speed		Gallon per acre2/	Drops per square centimeter		
				Feet	*Miles per hour*	*Feet*				*Microns*
1	5	8002	74	50	50	160	0.178	90	19	106
2	4	8010	16	50	50	295	.309	86	48	147
3	5	8010	22	50	70	186	.365	54	33	144
4	2	8010	28	50	90	175	.420	111	44	126
5	3	8020	8	50	50	297	.240	34	38	3/183
6	3	8020	8	100	50	273	.361	53	55	184
7 3/	1	8020	8	200	50	240	.332	21	43	179

1/ The swath width is that part of the swath having 0.1 gallon per acre or greater at each sampling point.

2/ At a nozzle pressure of 60 pounds per square inch.

3/ No replications.

a wider overall swath, but a large portion of those swaths had a deposit level lower than that which was acceptable. It should be pointed out that all of the flights were single passes and the lower level of deposit at the edges of the swath would be filled in by adjoining swaths under normal spray operations.

A comparison of swath width for the 50-, 70-, and 90-miles-per-hour flying speeds, using the same nozzle (treatments 2, 3, and 4, respectively), shows the same trend as with different size nozzles at one speed. The faster flying speeds produced a finer atomization which resulted in narrower acceptable swath widths. This similarity is to be expected since both methods change the degree of atomization.

There was some difficulty in assessing the effect of spraying height on the swath width (treatments 5, 6, and 7). As the spraying height was increased, it became more difficult to catch the entire spray swath on our 500-foot sampling platform due to drifting. The acceptable swath width was widest at the lowest (50-foot) flying height. This is contrary to what one might expect; however, we suspect that due to the tremendous rotor downwash from this aircraft, there is a cushioning effect at ground level causing the spray to bellow out from the center of flight. When the airspeed or the flying height is increased, the effect of rotor downwash at ground level is lessened (USDA Forest Service 1969).

In forest spraying operations, this downwash and rotor wake may be advantageous since there would be very little, if any, cushioning effect. The downwash may enhance spray penetration and deposition on the foliage or insect.

Spray Deposit and Pattern

Data from several of the flights were discarded because a large portion of the spray drifted off the platform. Most of the replicated flights showed large variations in spray patterns, deposit, and recovery levels, making it difficult to establish whether these differences were a result of the aircraft and spray system or the meteorological conditions during the flight. Figures 4-10 show the spray pattern of individual flights for each treatment parameter. Under upwind flight conditions, the 205A-1 produced two very high peaks with a low cradle between, similar to that of small fixed-wing aircraft flying at low elevation (Chamberlin et al. 1955, Isler and Yuill 1964). Small helicopters produce these same peaks and cradles but they are not as extensive (Isler and Maksymiuk 1961). Based on visual observations, the 205A-1 produced larger, more pronounced vortexes than the small helicopters, which could account for the more accentuated peaks and cradles. The mean deposit level in terms of gpa and drops per square centimeter for the entire swath varied considerably between the various treatment parameters (table 3). But then so did the swath widths on which these averages were based, as shown by the individual flight data in table 4. The narrower the swath, the higher the deposit level, assuming the spray was not lost to the atmosphere and the treatment parameters were the same.

Treatments 2 and 4 appear to give the best coverage. These treatments gave the higher degree of recovery, considering the swath deposit in terms of gpa and number of drops per square centimeter. Both of these treatments have atomizations within the 125-150-micron vmd range. Treatment 6 might appear to be the best since the swath width is wide, the deposit level in terms of gpa is high, and the degree of recovery is high. But treatment 6 is actually less desirable than treatments 2 and 4 because of the fewer drops per square centimeter, which is a result of the larger vmd (184 microns). This is not to say that treatment 6 would not be better in certain situations, such as under conditions which would prevent the smaller droplets from being deposited on the target, or where the smaller droplets did not contain enough active ingredient to give a high degree of mortality.

Table 4.--*Swath width, swath deposit, percent recovery, and atomization for individual test flights*

Treatment	Nozzle		Spraying		Flight number	Swath width[1]	Average swath deposit		Percent recovery	Atomization, vmd
	Tip size	Number	Height	Speed			Gallon per acre[2]	Number of drops per square centimeter		
			Feet	*Miles per hour*		*Feet*				*Microns*
1	8002	74	50	50	3	70	0.192	76	14	
					4	180	.137	87	15	
					5	140	.175	98	20	
					6	240	.189	91	23	101
					32	170	.195	98	23	112
					Mean	160	.178	90	19	106
2	8010	16	50	50	8	280	.334	78	50	152
					9	280	.350	77	52	
					10	270	.321	126	48	
					12	350	.232	62	42	142
					Mean	295	.309	86	48	147
3	8010	22	50	70	13	320	.202	66	34	
					14	180	.176	54	19	
					15	110	.608	69	39	141
					16	180	.357	36	38	
					30	140	.483	45	37	147
					Mean	186	.365	54	33	144
4	8010	28	50	90	17	180	.483	165	53	132
					31	170	.357	57	34	119
					Mean	175	.420	111	44	126
5	8020	8	50	50	26	310	.247	37	41	
					27	270	.280	34	41	183
					29	310	.193	30	32	
					Mean	297	.240	34	38	183
6	8020	8	100	50	23	250	.409	59	60	182
					24	300	.347	54	57	187
					25	270	.326	46	49	
					Mean	273	.361	53	55	184
7	8020	8	200	50	20	240	.332	21	43	179

[1] The swath width is that part of the swath having 0.1 gallon per acre or greater at each sampling point.

[2] At a nozzle pressure of 60 pounds per square inch.

Figure 4.--Spray pattern for individual flights -- treatment 1: 8002 nozzle tip, 50-foot spraying height, 50 miles per hour.

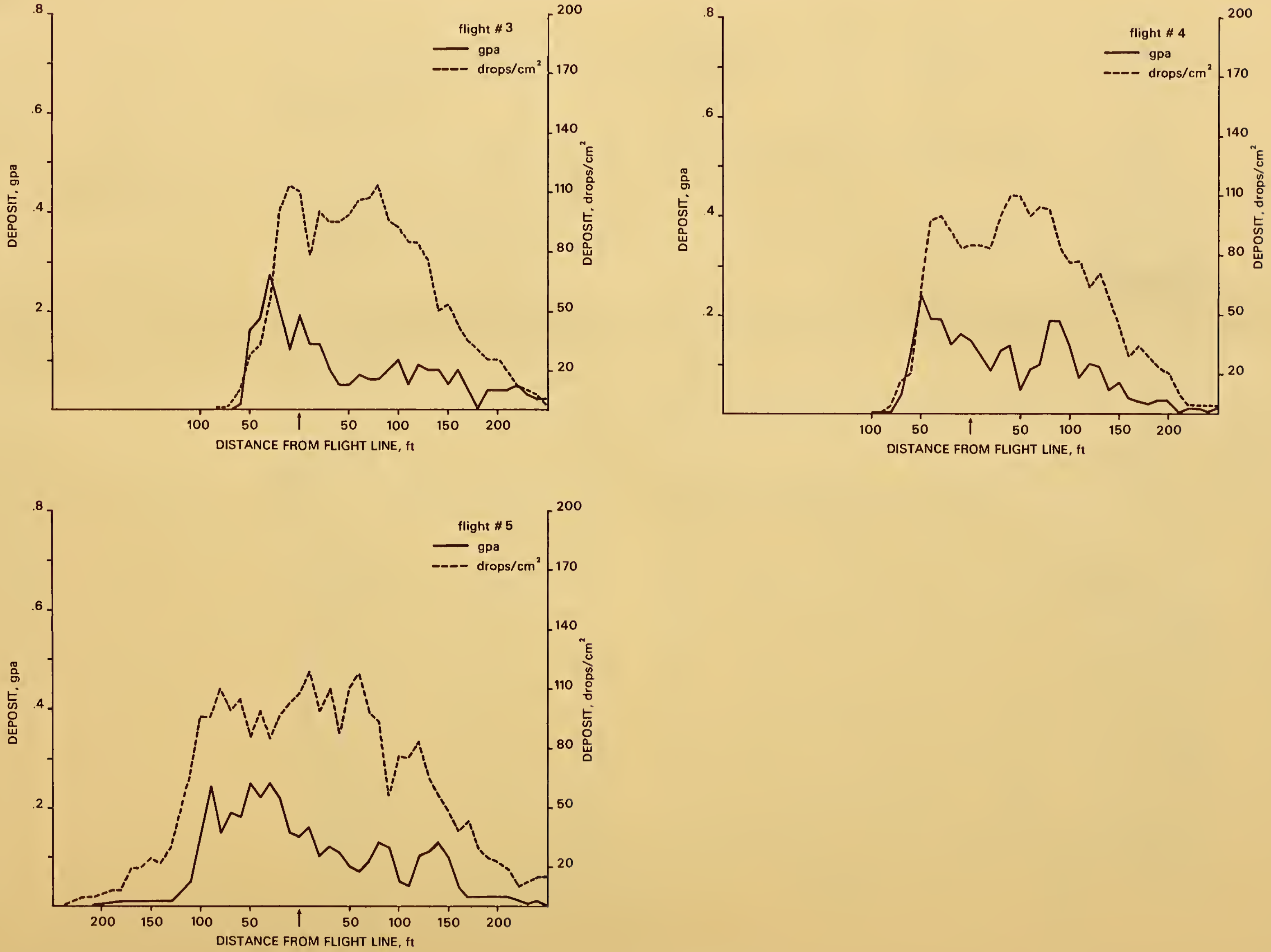


Figure 4.--Spray pattern for individual flights -- treatment 1: 8002 nozzle tip, 50-foot spraying height, 50 miles per hour (continued).

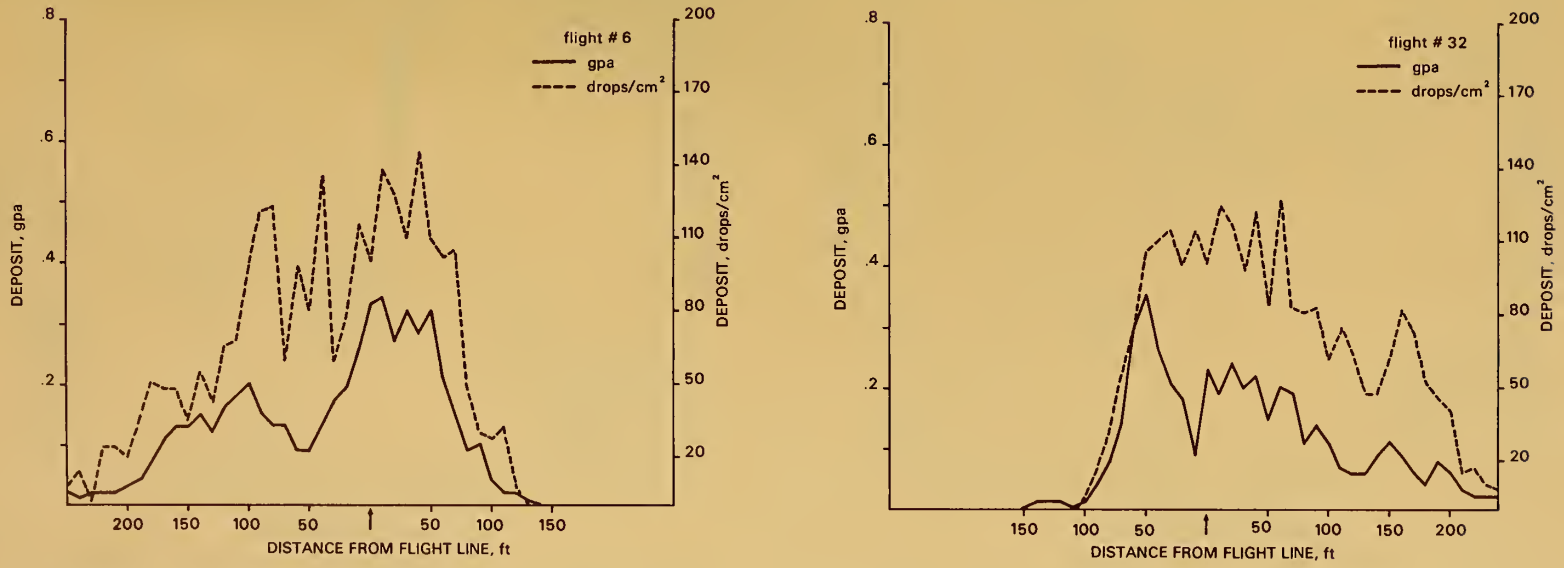


Figure 5.--Spray pattern for individual flights -- treatment 2: 8010 nozzle tip, 50-foot spraying height, 50 miles per hour.

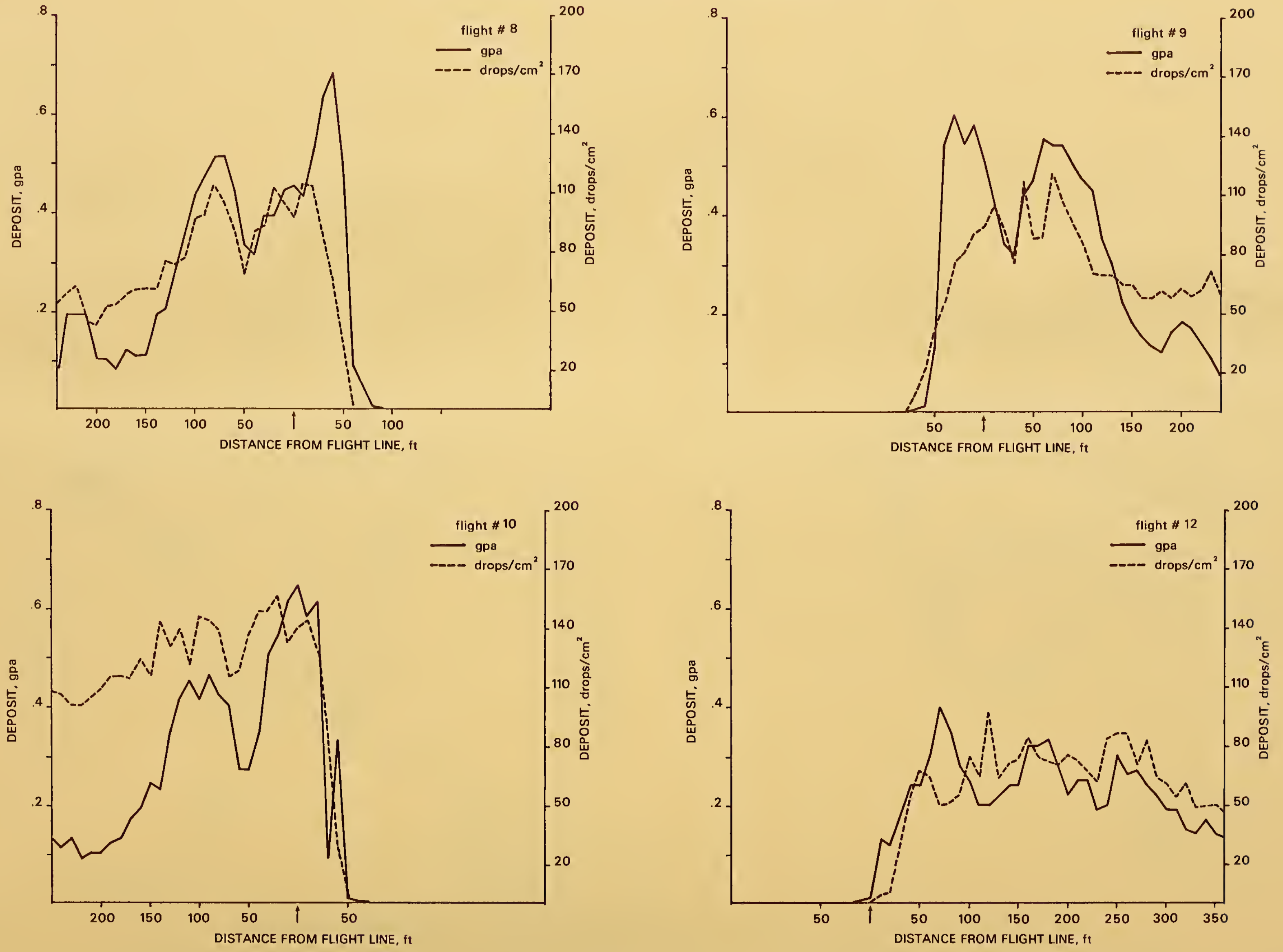


Figure 6.--Spray pattern for individual flights -- treatment 3: 8010 nozzle tip, 50-foot spraying height, 70 miles per hour.

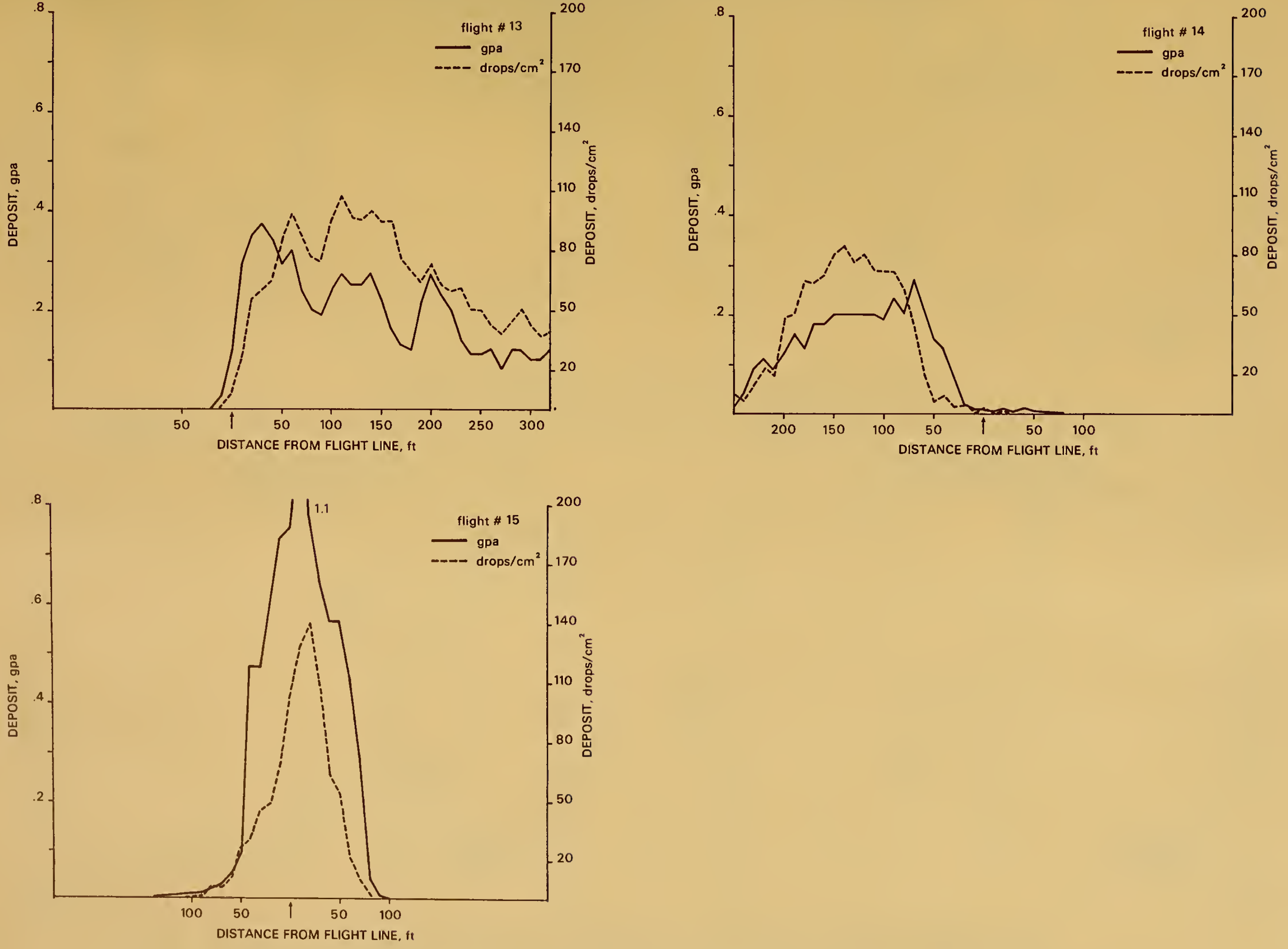


Figure 6.--Spray pattern for individual flights -- treatment 3: 8010 nozzle tip, 50-foot spraying height, 70 miles per hour (continued).

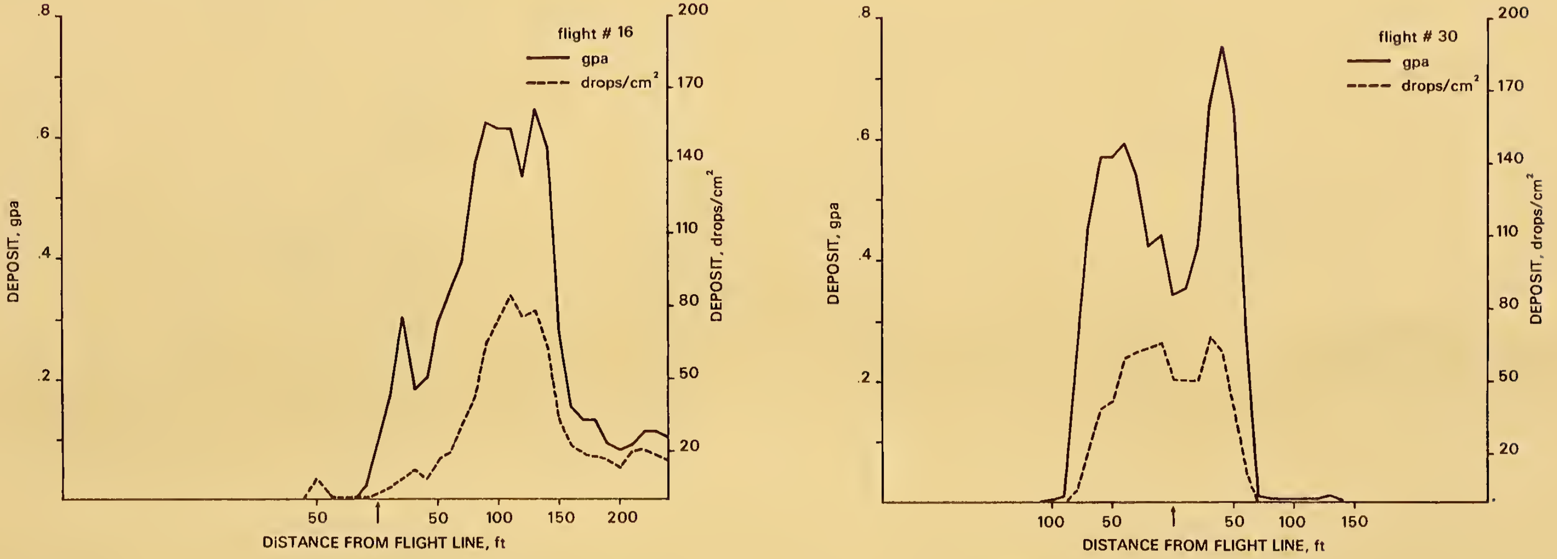


Figure 7.--Spray pattern for individual flights -- treatment 4: 8010 nozzle tip, 50-foot spraying height, 90 miles per hour.

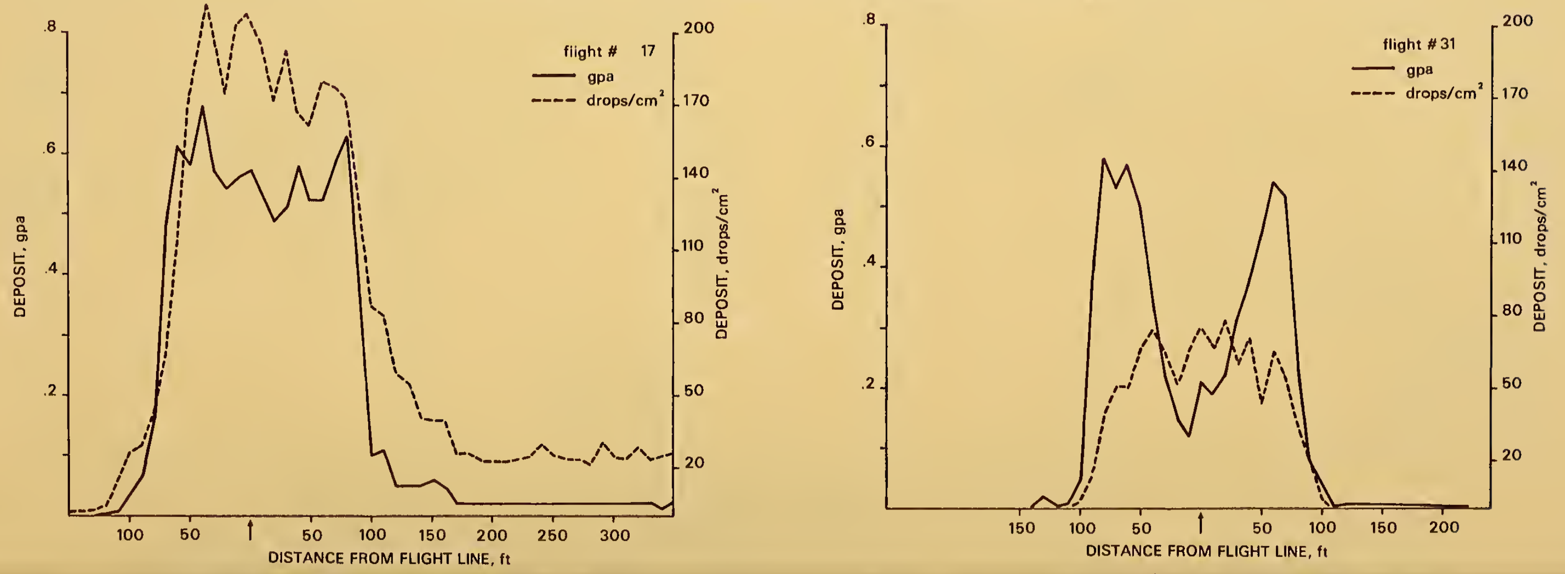


Figure 8.--Spray pattern for individual flights -- treatment 5: 8020 nozzle tip, 50-foot spraying height, 50 miles per hour.

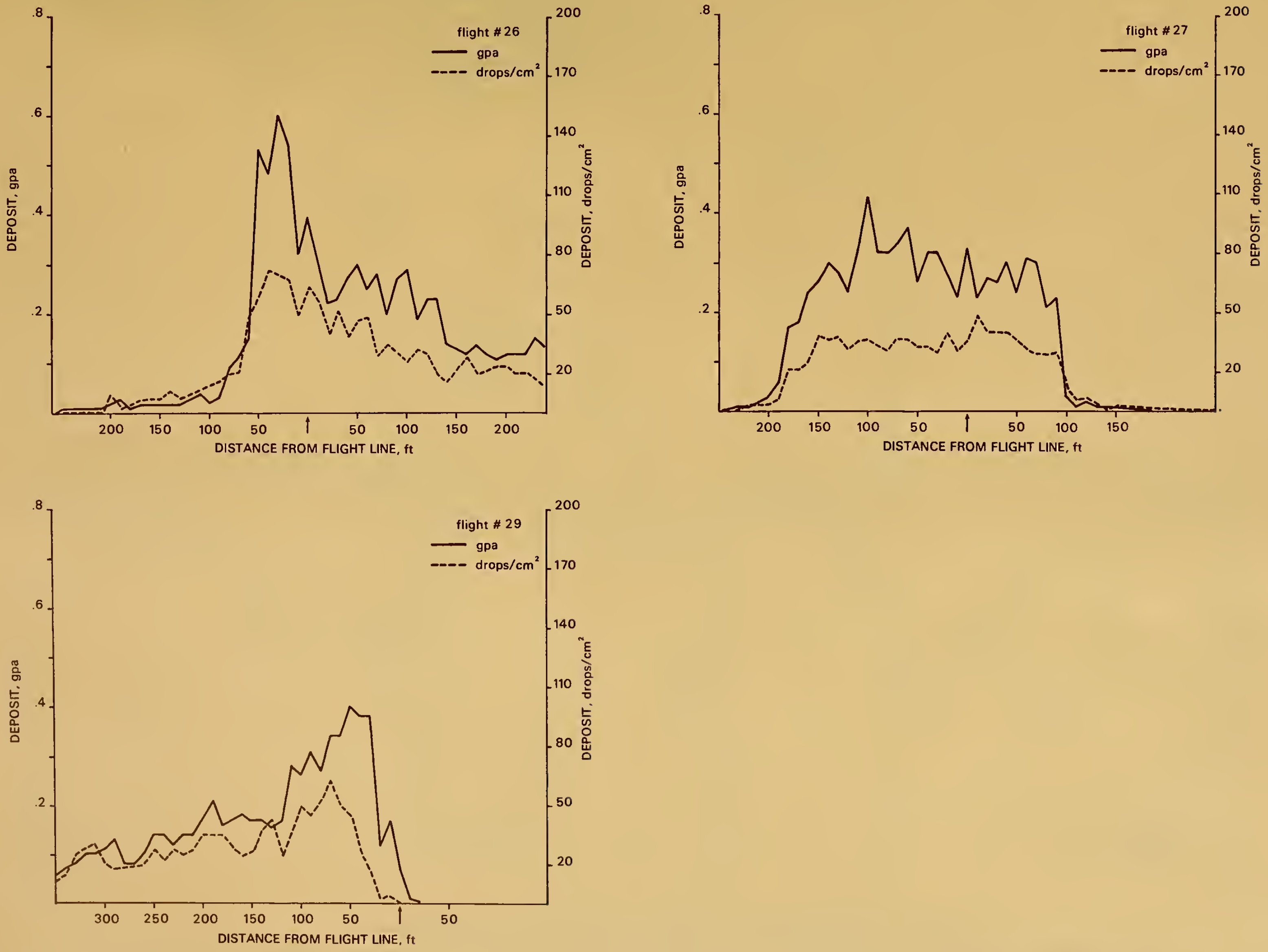


Figure 9.--Spray pattern for individual flights -- treatment 6: 8020 nozzle tip, 100-foot spraying height, 50 miles per hour.

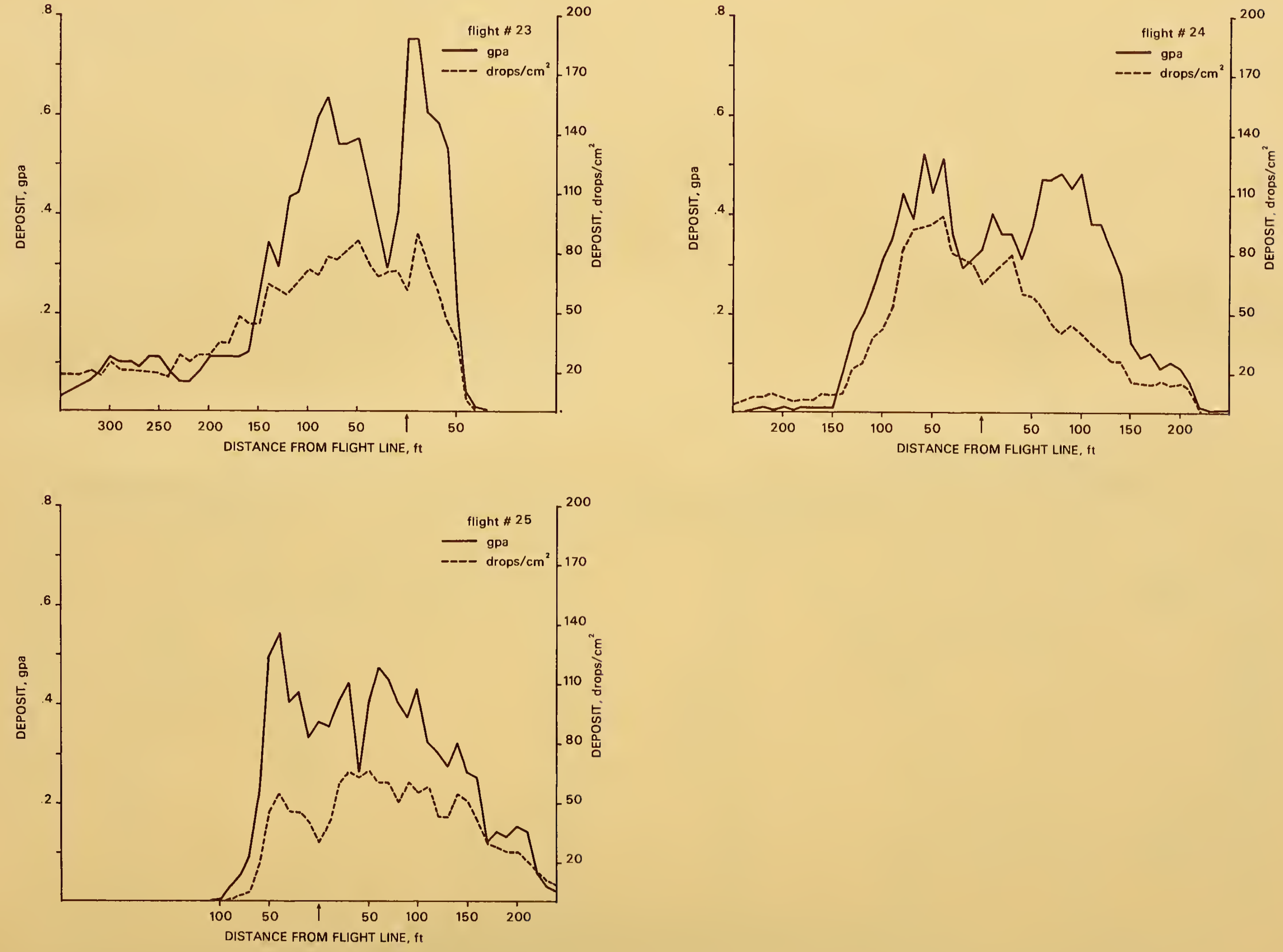
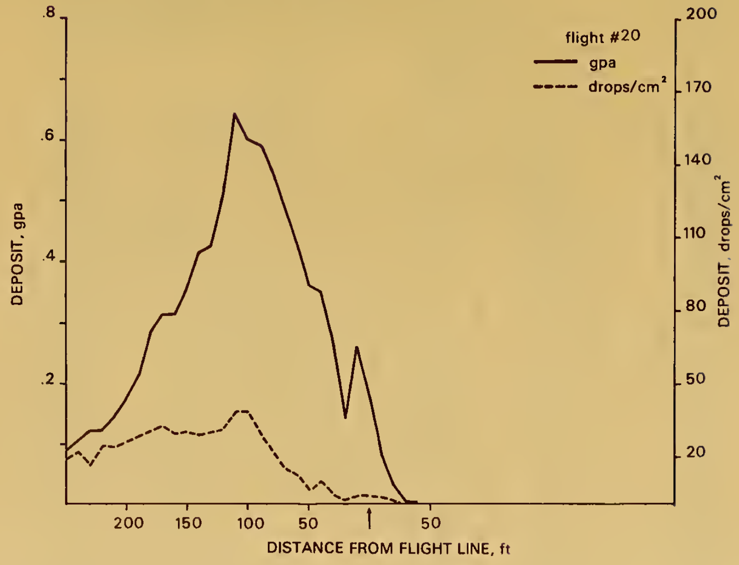


Figure 10.--Spray pattern for individual flights -- treatment 7: 8020 nozzle tip, 200-foot spraying height, 50 miles per hour.



Spray Recovery and Atomization

Table 3 shows that there was an average of only 40 percent of the spray recovered from the 205A-1, and, generally speaking, there was a higher level of deposit recovered from those flights having the larger atomization. There is no obvious explanation for this low recovery level. For open-ground tests, using an oil-base formulation, an average of 73 percent of the spray was recovered from a Bell 47D series helicopter (Isler and Maksymiuk 1961), 75 percent was recovered from a Piper PA-18A (Isler and Yuill 1964), and 76 percent was recovered from a Stearman (Isler and Yuill 1963).

The atomizations observed are in the range produced by aircraft operating under similar treatment parameters (unpublished data). There appears to be no unusual effect on atomization created by the 205A-1.

PERFORMANCE OF THE BELL 205A-1 UNDER FOREST SPRAYING CONDITIONS

Following completion of the airport test, it was concluded that the 205A-1 could be used for aerial application of Zectran for forest insect control. Accordingly, two Bell 205A-1 helicopters were used for the 1973 Douglas-fir tussock moth operational test in northeastern Oregon and southeastern Washington. Before spraying, the helicopters were calibrated to deliver 1 gpa at a speed of 90 miles per hour and a swath width of 200 feet using Spraying Systems TeeJet flat fan nozzle tips No. 8020 at 60 pounds per square inch and later changing to 45 pounds per square inch. The average load at 3,000- to 5,000-foot elevation was 250 gallons and the minimum loading time was 3 minutes with an average of 4 minutes. The average speed while ferrying was 120 miles per hour. The atomization of spray recovered at ground level at two different spray areas was 211 and 226 microns, vmd. Additional performance data are given in table 5.

Table 5.--*Field performance data of two Bell 205A-1 helicopters used in an operational insecticide spray test*

Item	Aircraft number		Average
	50-R	57	
Acres sprayed	63,718	52,545	58,132
Flight hours[1]	73' 50"	58' 47"	66' 18"
Acres per hour[1]	863.4	893.6	876.8
Flight days	29	25	27
Acres per flight day	2197.2	2101.8	2153.0
Hours per flight day	2.54	2.35	2.46
Cost per flight hour[1]	$1,759.81	$1,319.85	$1,564.71
Cost per acre[2]	$2.038	$1.477	$1.785

[1] Includes ferrying time.

[2] Cost includes ferrying time but does not include standby time or insecticide costs.

CONCLUSIONS

1. There was no practical difference in flow rate between nozzles placed at various locations on the boom.
2. The spray system was very easy to calibrate, there was good agitation in the tank, and the boom could be rotated to adjust nozzle orientation with respect to the line of flight.
3. The vortexes appeared to be much stronger and much more pronounced than those of smaller helicopters.
4. The system produced larger than normal deposit peaks and valleys, which may possibly be explained by the absence of nozzles over a 12-foot, 8-inch center section of the boom or by the very strong rotor wake and downwash.
5. The largest of the three nozzle tips tested produced the widest acceptable swath width.
6. By increasing the spraying height from 50 feet to 100 and 200 feet, the spray is dispersed over a larger area reducing the acceptable swath width and the pilot's control over where the spray is deposited.
7. The swath widths produced by this aircraft and the spray system were definitely larger than those of a smaller helicopter.
8. This aircraft should be further tested to establish the effect of rotor wake, vortexes, and downwash on dispersal of the spray under open ground and forest conditions.

LITERATURE CITED

Chamberlin, Joseph C., Charles W. Getzendaner, Harold H. Hessig, and V. D. Young
1955. Studies of airplane spray-deposit patterns at low flight levels. U.S. Dep. Agric. Tech. Bull. No. 1110, 45 p., illus.

Isler, D. A., and Bohdan Maksymiuk
1961. Some spray distribution and atomization tests with a helicopter. U.S. Agric. Res. Serv. ARS 42-54, 9 p., illus.

__________ and J. S. Yuill
1963. Spray distribution patterns from a Stearman airplane flying at 50 feet. U.S. Agric. Res. Serv. ARS 42-82, 22 p., illus.

__________ and J. S. Yuill
1964. Spray distribution patterns from a Piper PA-18A airplane flying at 50 feet. U.S. Agric. Res. Serv. ARS 42-88, 17 p.

Maksymiuk, Bohdan
1964. The drop size spectra method for estimating mass median diameter of aerial sprays. USDA For. Serv. Res. Pap. WO-1, 9 p.

USDA Forest Service
1969. Helicopter rotor downwash effects. U.S. Dep. Agric., For. Serv. Equip. & Dev. Cent., San Dimas, Calif., ED & T 1818, 13 p.

Yates, W. E., and N. B. Akesson
1963. Fluorescent tracers for quantitative microresidue analysis. Am. Soc. Agric. Eng. Trans. 6: (2) 104-107, 114.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife -- if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

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